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LABORATORY INFECTION OF SPIDERS AND HARVESTMEN (ARACHNIDA: ARANEAE AND OPILIONES) WITH *NEOAPLECTANA* AND *HETERORHABDITIS* NEMATODES (RHABDITOIDEA)

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ABSTRACT

Specimens of the aerial spiders, *Pholcus phalangiodes* and *Latrodectus mactans,* a ground spider, *Pirata* sp., and a harvestman, *Phalangium* sp., were placed on damp filter paper containing the entomogenous nematodes, *Neoaplectana carpocapsae* and *Heterorhabditis heliothidis.* Representatives of all four hosts were killed by the above nematodes. In *Pholcus, Pirata* and *Latrodectus,* the nematodes developed to the adult stage but did not multiply. In the case of *Phalangium,* the nematodes reproduced and formed infective juveniles. The present report establishes that under ideal conditions, neoaplectanid and heterorhabditid nematodes are capable of infecting, killing and with one host, reproducing in arachnids.

INTRODUCTION

With the commercialization of nematodes belonging to the genera *Neoaplectana* and *Heterorhabditis* for insect control, studies are being undertaken to determine what effect these nematodes may have on non-insect arthropods. *Neoaplectana carpocapsae* and *Heterorhabditis heliothidis* are known to infect a range of insects under laboratory conditions but have never been tested against members of the class Arachnida. The host range and biology of these nematodes are summarized by Poinar (1979).

The present paper reports infectivity tests made with *N. carpocapsae* and *H. heliothidis* in the laboratory against three species of spiders and a harvestman.

MATERIALS AND METHODS

For the present tests, the aerial spiders, *Pholcus phalangiodes* (Pholcidae) and *Latrodectus mactans,* a ground spider, *Pirata* sp. (Lycosidae), and a harvestman, *Phalangium* sp. (Phalangidae) were used.

The nematodes employed were the 42 strain of *Neoaplectana carpocapsae* Weiser and the NC strain of *Heterorhabditis heliothidis* (Khan, Brooks and Hirschmann).

The infection chambers for *Pholcus, Pirata* and *Latrodectus* were plastic vials (65 mm long by 25 mm in diameter) which were lined with filter paper. The inner area of the exposed filter paper was 65 mm x 80 mm or 52 cm.^{2} A single spider was placed in each vial. The inoculum consisted of 0.5 cc of infective stage nematodes applied in an aqueous mixture to the filter paper in each vial. The spiders were exposed to nematodes over most of the surface (except for the bottom and top of the vial). The nematode concentrations consisted of 10.7 x 10^4/cc for *H. heliothidis* and 12 x 10^4/cc for *N. carpocapsae,* making the dosage rate approximately 1028 nematodes/cm^2 for *H. heliothidis* and approximately 1150 nematodes/cm^2 for *N. carpocapsae.* Fifteen adult specimens of each spider were used in these experiments. Six were challenged with *N. carpocapsae,* six with *H. heliothidis* and three served as controls. In the controls, only 0.5 cc of water was added to the filter paper.

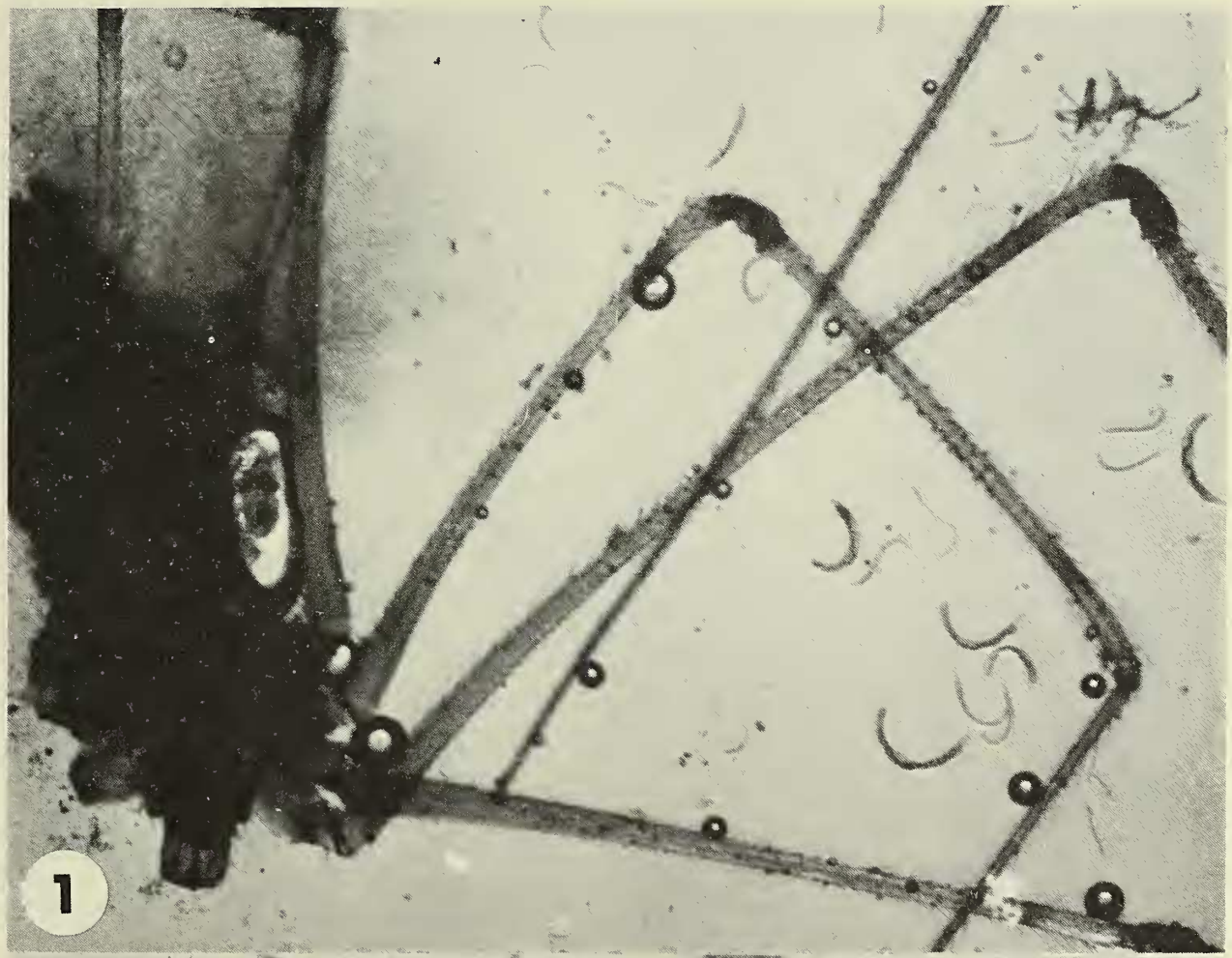
Because of their larger size the harvestmen were placed together in containers measuring 140 mm x 190 mm x 90 mm containing filter paper in the bottom. The area of the filter paper was 266 cm^2. Approximately 10 cc of the nematode mixtures were added to the filter paper making the nematode concentration approximately 4022 nematodes/cm^2 for *H. heliothidis* and approximately 4511 nematodes/cm^2 for *N. carpocapsae.* Ten harvestmen were placed in a container with *H. heliothidis,* ten with *N. carpocapsae* and nine served as controls (with water only).

The experiments lasted for 20 days. Water was periodically added to the filter paper to keep the nematodes viable. At the time of death, the arachnid was removed and a sample of blood drawn and plated out on Tergitol 7 plus TTC (triphenyltetrazolium chloride) agar. The symbiotic bacteria that are carried by the nematodes and released when they enter the host's hemocoel (*Xenorhabdus* spp.) (Thomas and Poinar 1979) turn a characteristic blue color on Tergitol 7 plus TTC agar. A positive color reaction from blood samples indicates a successful infection and the probable cause of death. This test is especially useful to determine infections when the nematode is not able to reproduce or perishes after entering the host.

RESULTS

The results of challenging three species of spiders and a harvestman with *N. carpocapsae* and *H. heliothidis* nematodes are summarized in Table 1. In every category, mortality as a result of nematode activity was obtained. The controls of *Pholcus, Pirata* and *Latrodectus* were all alive at the end of the experimental period, yet 67% of the control harvestmen perished. None of the controls showed evidence of nematode infection and death of the harvestmen was attributed to possible cannibalism.

With all hosts, those that died showed the presence of *Xenorhabdus* bacteria in their hemocoel shortly after death and later also exhibited mature nematodes in their body cavities (Figs. 1-4). However, although both *N. carpocapsae* and *H. heliothidis* were able to penetrate and develop to the adult stage in the hemocoel of the test spiders, reproduction and the production of infective stages occurred only in the phalangid host. With the latter, six harvestmen infected with *N. carpocapsae* produced a total of 43,000 infective juveniles (ca. 7,200 per host) and five harvestmen infected with *H. heliothidis* produced a total of 130,000 nematodes (26,000 per host).



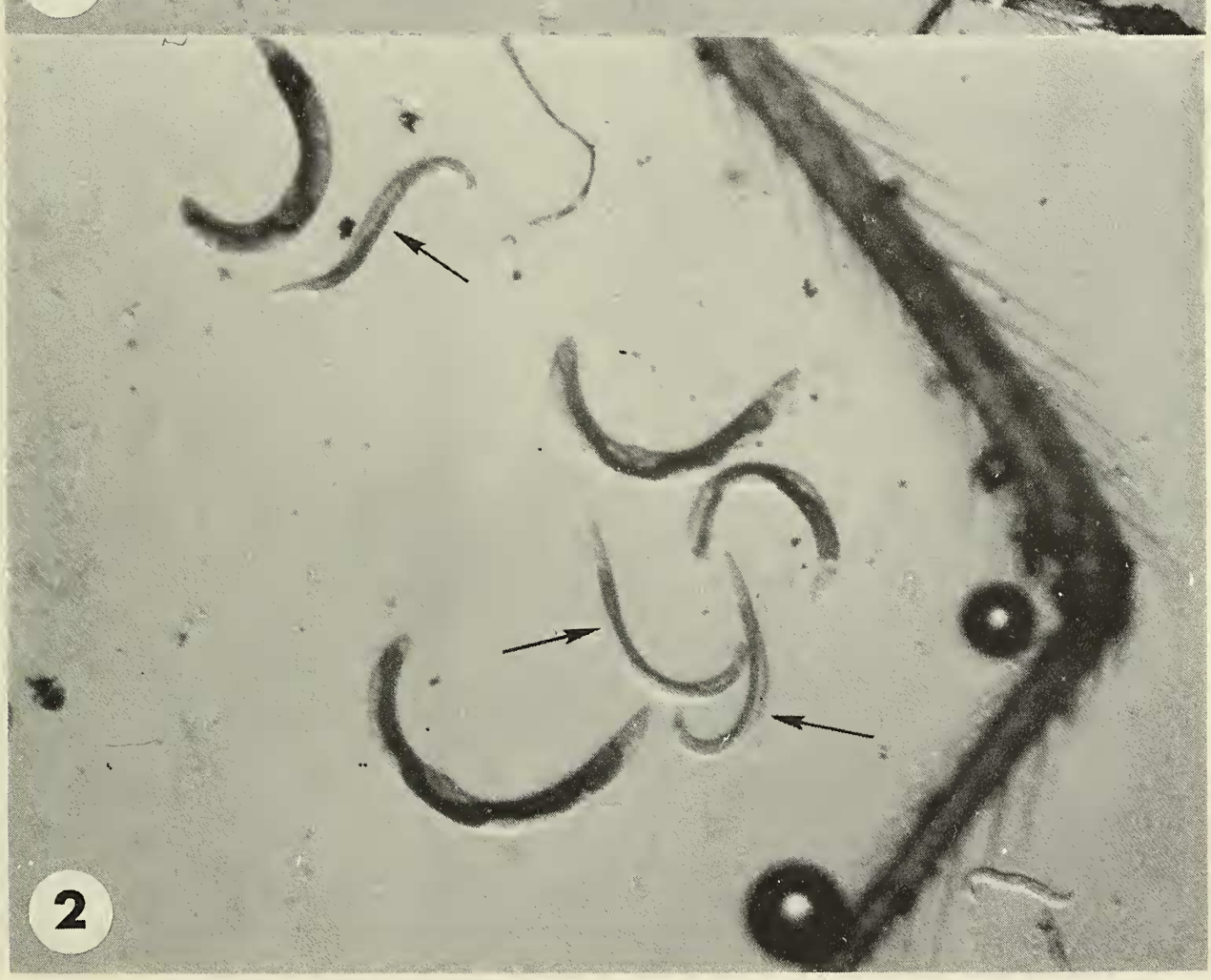


Fig. 1.—*Pholcus phalangiodes* killed by *Neoaplectana carpocapsae.* Adult nematodes removed from the spider's body are on the right side of the figure.

Fig. 2.—Detail mature females and males (arrows) of *Neoaplectana carpocapsae* removed from the body cavity of an infected *Pholcus phalangiodes.*

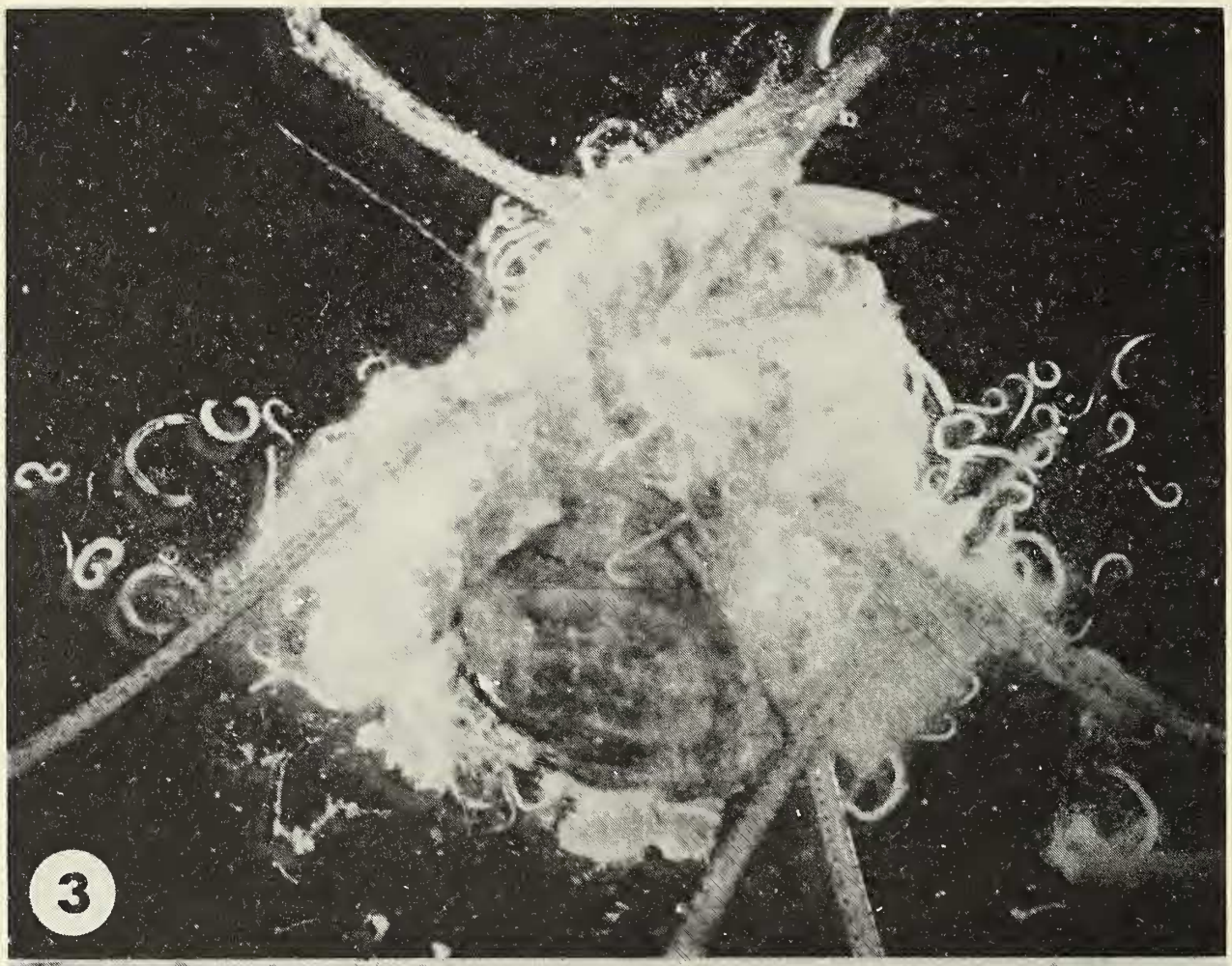


Fig. 3.—A *Phalangium* sp. killed by *Neoaplectana carpocapsae*. Note developing nematodes adjacent to the opened body.

Fig. 4.—Detail of developing female *Neoaplectana carpocapsae* removed from the body cavity of a *Phalangium* sp. Note juvenile nematodes developing inside a mature female (arrow).

Table 1.—Results of challenging three spiders and a harvestman with *N. carpocapsae* and *H. heliothidis*.

Host	Number of Individuals Dead After 20 Days[1]		
	with *N. carpocapsae*	with *H. heliothidis*	control
Pholcus phalangiodes	6(100%)	3(50%)	0
Pirata sp.	3(50%)	4(66%)	0
Latrodectus mactans	6(100%)	6(100%)	0
Phalangium sp.	6(60%)	5(50%)	6(67%)

[1] The number in parenthesis refers to the percentage of those exposed that died.

DISCUSSION

The present tests are interesting because they show that some members of the class Arachnida are subject to infection by neoaplectanid and heterorhabditid nematodes.

These nematodes are able to invade and develop to the adult stage in the aerial spiders *Pholcus phalangiodes,* and *Latrodectus mactans,* a ground spider(*Pirata* sp.), and a harvestman (*Phalangium* sp.). However, only in the harvestmen was nematode reproduction complete and infective juveniles formed.

One reason for the lack of reproduction in the spider hosts could be due to the presence of foreign bacteria. In many hosts, a strain of *Pseudomonus aeruginosa* appeared soon after the spider died. This bacterium was noted to reproduce rapidly and fill the cadaver, thus competing with the symbiotic bacteria (*Xenorhabdus* sp.) which are necessary for nematode reproduction (Poinar 1979).

In conclusion, although spiders and harvestmen can be infected by neoaplectanid and heterorhabditid nematodes, they are only slightly susceptible in comparison with most insects. There is no record of a spider parasitized by these nematodes in nature, though there are reports of spider parasitism by mermithid nematodes (Poinar 1985).

Most spiders would normally not become infected during the mass release of nematodes on the soil surface for insect control. The aerial spiders would be protected by the nature of their habitat. The rapid movement of many ground spiders would be detrimental for nematode attachment and during periods of activity the phalangids would normally carry their bodies too high for the nematodes to reach. Such forms could be infected only during periods of quiescence.

ACKNOWLEDGMENTS

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